U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-256 937

Review of the Causes of Waterborne Disease Outbreaks

National Environmental Research Center

June 1971

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No. PB-256 937
4. Title and Subtitle Review of the Causes of Waterborne Disease Outbreaks.			5. Report Date June 1971 6.
7. Author(s) Gunther F. Craun, and Leland J. McCabe			8. Performing Organization Rept. No.
9. Performing Organization Name and Address National Environmental Research Center Cincinnati, Ohio Water Supply Research Laboratory			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes Presented at the American Water Works Association Annual Meeting, Held at Denver, Colorado, June, 1971.

16. Abstracts

Waterborne outbreaks occur because of inadequacies in water systems and deficiencies in their operation. Unless needed improvements are made in both public and private water systems, it is expected that a residual number of outbreaks will continue to occur in this country. The disinfection of ground water systems would be a relatively easy and simple means to reduce waterborne disease.

17. Key Words and Document Analysis. 17a. Descriptors

*Infectious diseases
*Water supply
*Potable water
Public health
Sanitary engineering
Water pollution
Contamination
Microorganisms
Tables(Data)

17b. Identifiers/Open-Ended Terms

Waterborne
Water pollution effects(Humans)

17c. COSATI Field/Group 6E, 6M, 13B

18. Availability Statement National Technical Information Service Springfield, VA 22161	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 60
	20. Security Class (This Page) UNCLASSIFIED	22. Price PC$4.50/ MF$2.25

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

246116

PB 256 937

002156

PREPUBLICATION COPY

REVIEW OF THE CAUSES OF WATERBORNE DISEASE OUTBREAKS*

by

Gunther F. Craun
Waterborne Disease Section
Criteria Development Branch

and

Leland J. McCabe
Chief, Criteria Development Branch
Water Supply Research Laboratory

ENVIRONMENTAL PROTECTION AGENCY
NATIONAL ENVIRONMENTAL RESEARCH CENTER
Water Supply Research Laboratory
4676 Columbia Parkway
Cincinnati, Ohio 45268

Presented at

American Water Works Association
Annual Meeting
Denver, Colorado
June 1971

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

Currently, about 14 waterborne disease outbreaks occur each year in this country. These outbreaks cause on the average, 1600 illnesses and one death per year. This is not a leading cause of the American public's illness, but it represents a residual that should have been eliminated in this age of sanitation. The nature of waterborne disease outbreaks is reviewed with particular emphasis on deficiencies in water supply systems and operational practices that allowed the outbreaks to occur. To update the record, waterborne outbreaks occurring during the ten-year period 1961-70 were compiled and analyzed.(1)

Only outbreaks associated with water used for drinking or domestic purposes are included in this analysis. To be considered an outbreak, at least two cases of infectious disease had to be reported. Except in very unique circumstances, such as one chemical poisoning where the poison was detected in the water, a single isolated case cannot be recognized as having been caused by drinking water. But with two or more cases a common source can be noted and investigated.

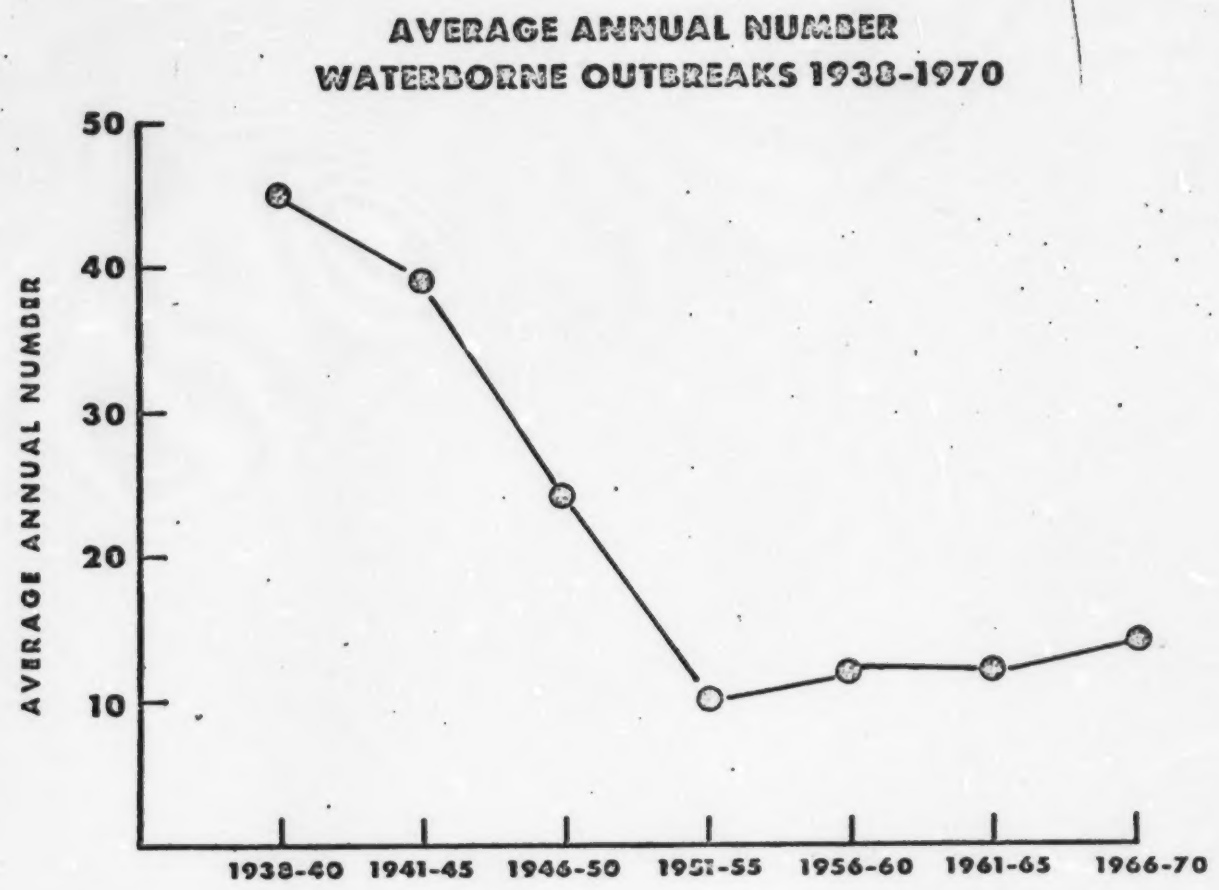
The investigation of outbreaks is often incomplete and conducted long after the outbreak occurred; consequently, relatively few outbreaks can be considered as proven to have been caused by drinking water. The waterborne hypothesis, however, was the most logical explanation for these outbreaks. The Riverside, California, outbreak in 1965 might be

considered to be a proven waterborne outbreak because the etiological agent was isolated from the water. But even after months of investigation, the exact circumstances responsible for the outbreak could not be determined.(2,3,4,5)

Similar criteria were used to define waterborne outbreaks in the two previous reviews, Weibel, et al.(6) for the period 1946-60 and Eliassen and Cummings(7) for the period 1938-45. These data are thus considered to be compatible with that for the period 1961-70, especially in noting trends. A criterion of five cases of illness was used by Gorman and Wolman(8) to define an outbreak in their review of waterborne disease for the period 1920-36.

Historical Trends

Waterborne disease data over the last three decades indicate that outbreaks are no longer on the decline in this country. The decline in the number of outbreaks that was noted in the previous review(6) seems to have leveled off in recent years. This trend is depicted in Figure 1. A consistent and dramatic decrease took place from the period 1938-40 to 1951-55 when the number of waterborne outbreaks dropped from an average of 45 per year to 10 per year. Since the 1951-55 period,


AVERAGE ANNUAL NUMBER
WATERBORNE OUTBREAKS 1938-1970
AVERAGE ANNUAL NUMBER
50
40
30
20
10
1938-40
1941-45
1946-50
1951-55
1956-60
1961-65
1966-70

however, there has been no decline in the average annual number of outbreaks, but rather a slight increase has occurred. It is not known if the average of 14 outbreaks noted during the period 1966-70 represents a real increase or is due to certain inherent factors, such as differences in reporting, and this particular point is difficult to quantitate. What is significant is that no decline is apparent, and if similar conditions exist in the future, an average of over one outbreak per month can be expected to continue. The possible causes that may be responsible for this residual number of outbreaks are examined in this paper.

Outbreaks were categorized by type of system in order to determine if there was a difference in trends exhibited by community and household water systems. As noted in Table 1, public and private systems* each display a pattern quite similar to that when the systems are considered together.

---

*The terms public and private as used in this paper refer not to the ownership of the utility but to the type of service it renders. Generally, public supplies are municipal-type supplies available to all within a certain area. Private supplies include individual and semi-public supplies, such as provided by camps, resorts, hotels, industries, institutions, etc.

TABLE 1

AVERAGE ANNUAL NUMBER

WATERBORNE OUTBREAKS 1938-1970

	OUTBREAKS		
	PUBLIC SYSTEMS	PRIVATE SYSTEMS	ALL SYSTEMS
1938-45	12	26	38
1946-50	6	17	23
1951-55	3	7	10
1956-60	5	7	12
1961-65	3	8	11
1966-70	4	10	14

Thus, it cannot be said that an increase of outbreaks in one type system disguises a decrease of outbreaks in the other type system.

An indication of the relative size of outbreaks since 1938 is presented in Table 2. Generally speaking, the size of outbreaks for all systems appeared to level off during the period 1946-50 at about 100 illnesses per outbreak. This trend, however, was markedly changed during the period 1961-65 by two particularly large outbreaks that occurred in public systems - Riverside, California, and Gainesville, Florida. The 680 cases of waterborne disease per outbreak during this period was the highest for any period from 1938 to the present.

Public and private systems each exhibit slightly different trends as to outbreak size if considered separately. The size of outbreaks in private systems increased to 93 illnesses per outbreak during 1966-70, primarily due to a number of large outbreaks associated with recreational areas. During the same period the size of outbreaks in public systems decreased to a low of 166 illnesses per outbreak.

TABLE 2.

CASES OF WATERBORNE DISEASE PER OUTBREAK 1938-1970

YEARS	ILLNESS PER OUTBREAK		
	PUBLIC SYSTEMS	PRIVATE SYSTEMS	ALL SYSTEMS
1938-45	1000	50	340
1946-50	292	43	114
1951-55	333	33	125
1956-60	207	23	103
1961-65	2603	39	680
1966-70	166	93	114

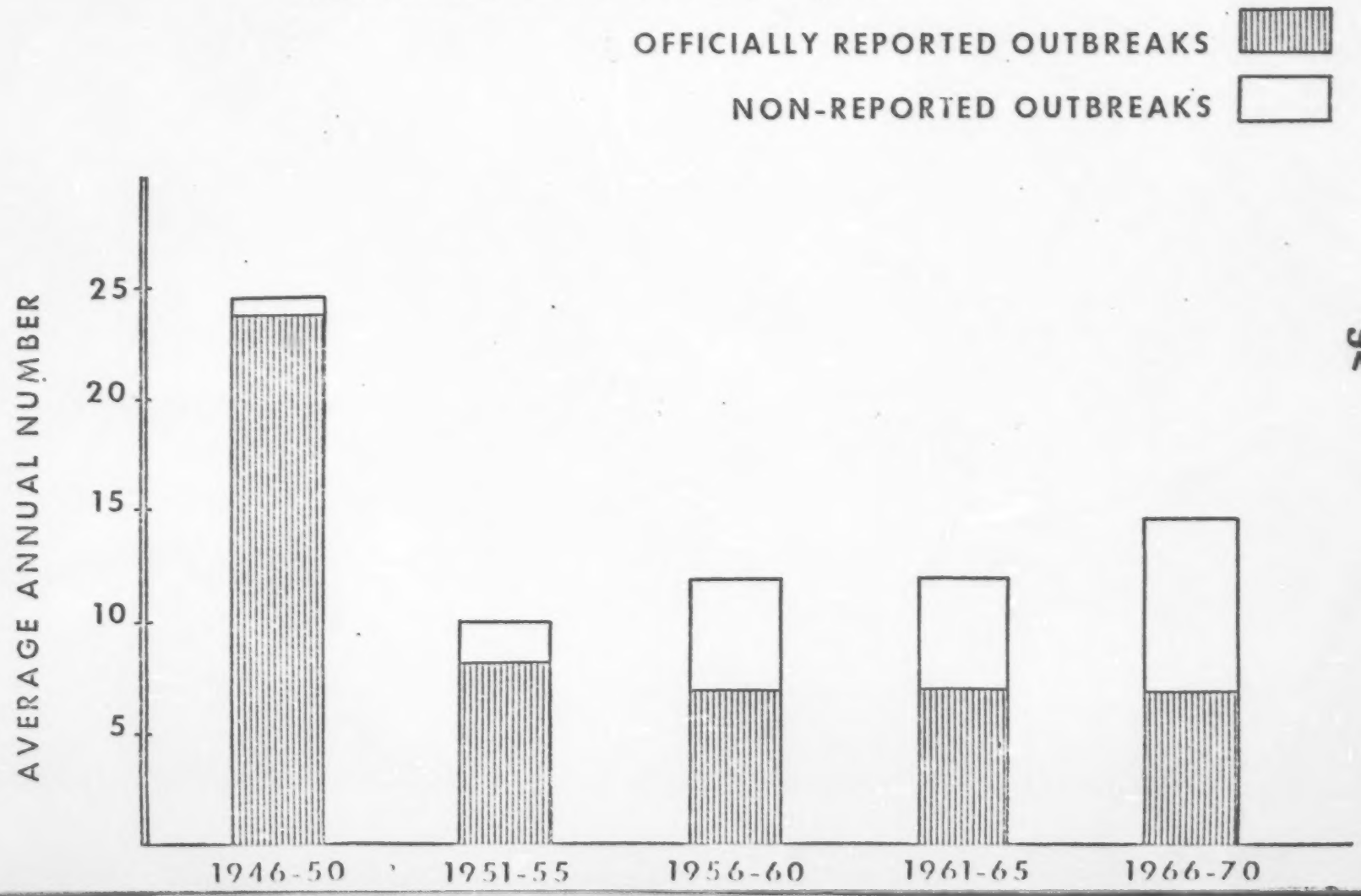
Reporting

The state health departments report the unusual occurrence of any disease to the National Center for Disease Control (NCDC) and this constitutes the primary source of information about waterborne outbreaks. However, additional outbreaks are often found by other means: (1) a review of the medical and engineering literature; (2) newspaper and newsletter clippings; (3) a survey of the state sanitary engineers and state epidemiologists; (4) data from the Division of Indian Health, U.S. Public Health Service. The relative number of outbreaks uncovered by these means is shown in Figure 2. Officially reported outbreaks as noted in Figure 2 and throughout this paper refer to outbreaks reported to NCDC. Only slightly more than half of the outbreaks found since 1956 were considered to have been reported.

A cursory review of the data in Figure 2 would either indicate that the reporting of waterborne outbreaks to NCDC has decreased in recent years or that a greater effort has been made to find the non-reported outbreaks. It is felt that the latter is probably the more important factor. In addition, the time period over which state health department officials are asked to recall outbreaks may be quite significant. For the 1946-60 review, state health

AVERAGE ANNUAL NUMBER
WATERBORNE - DISEASE OUTBREAKS FOUND DURING 1946-1970

REPORTED VERSUS NON-REPORTED



departments were surveyed in the early 60's and asked to add to the list of outbreaks prepared by the investigators. Many more outbreaks were added by this means for the period 1956-60 than the years 1946-55. Similarly, for the 1961-70 review, more outbreaks were found in the last five years than the first five. It is thought that by polling the state health department officials more often, such as every two to three years rather than once every ten to fifteen years, more outbreaks could be found.

Even though a number of outbreaks were uncovered by a rather extensive survey, it should be recognized that more outbreaks probably occurred but were not included because they either were not recognized or were investigated at the local level and never reported to state officials. There is no way to know how many of this type outbreak actually occurred and any number given would be strictly a guess. Nevertheless, an attempt was made to arrive at a reasonable estimate of how many waterborne outbreaks occurred but were not found during the review period 1946-1970.

If those states with good investigation and reporting of outbreaks could be identified, the records of

the other states could be compared to these. However, identifying the states having the greatest efficiency in finding outbreaks can pose somewhat of a problem. More outbreaks could occur in some states because of deficiencies in the water supplies of the state or because concerted effort was made by some states to uncover, investigate, and report outbreaks. Thus, it was decided to arbitrarily choose these states on the basis of waterborne outbreak rates. An outbreak rate (outbreaks per 1,000,000 people per year) was calculated for each state, based upon the outbreaks tabulated over the previous 25 years and the estimated population served over the same years. The overall rate calculated for the U.S. during this time period was 0.08 waterborne outbreaks per 1,000,000 people per year. Twenty states were found to have an outbreak rate for all systems that was equal to or greater than the U.S. average.

Having identified these twenty states, separate outbreak rates were then calculated for each by type of system: (1) a public system rate, the number of waterborne outbreaks per 1,000 facilities for the entire 25-year period; (2) a private system rate, the number of waterborne outbreaks per 1,000,000 people not served by public supplies per year.

It was felt that on the average, all states could be reporting outbreaks at a rate comparable to the twenty. If this is a reasonable assumption, it would be expected that the average outbreak rate for public systems in the U.S. would be 9.94 per 1,000 facilities rather than 5.66; for private systems 0.71 per 1,000,000 people per year rather than 0.23. This would mean that during the period 1946-70, only about 57 percent of the outbreaks occurring in public systems were tabulated; 33 percent for private systems. Unless reporting is improved, it is anticipated that only one of every two outbreaks occurring in public systems will be recognized and sufficiently publicized; only one of every three outbreaks in private systems. In this same regard, Reddick and Aycock(9) of the South Carolina Board of Health, noted a relatively low incidence of waterborne outbreaks in that state and stressed the need for a more accurate assessment of the situation by better reporting and documentation of outbreaks.

Six states reported no outbreaks during the 1961-70 period. This is not considered to represent the lack of occurrence of outbreaks, but more likely the lack of follow-up to determine what diseases are occurring and the reasons for occurrence. If a 25-year period is considered, there are only two states, Delaware and Rhode Island, where no outbreak is known to have occurred.

These are small states and the application of U.S. average rates to the number of public water systems and population not served by public systems would indicate that Delaware should have expected one private outbreak but no public outbreaks. No outbreaks in either public or private supplies were expected for Rhode Island. Two other states have an outbreak listed under protest. Improvements cannot be made in water supply practices unless problems are admitted to exist.

Latest Ten Years of Record

During the ten-year period 1961-70, there were 128 known outbreaks of disease or poisoning attributed to drinking water. These outbreaks resulted in 46,374 illnesses and 20 deaths. The number of outbreaks and cases of waterborne disease is shown in Table 3.

There were 94 outbreaks in private supplies and 34 outbreaks in public supplies. One outbreak resulted in two diseases; 110 cases of gastroenteritis occurred within 48 hours and after a longer incubation period,

Table 3

WATERBORNE-DISEASE OUTBREAKS 1961-70
BY TYPE OF ILLNESS AND SYSTEM

Illness	Private Systems		Public Systems		Total	
	Outbreaks	Cases	Outbreaks	Cases	Outbreaks	Cases
Gastroenteritis	25	4,498	14	22,048	39	26,546
Infectious Hepatitis	22	664	8*	239	30*	903
Shigellosis	16	939	3	727	19	1.666
Typhoid	14	104	-	-	14	104
Salmonellosis	4**	96	5	16,610	9**	16,706
Chemical Poisoning	7	42	2	4	9	46
Enteropathogenic *E. coli*	4	188	-	-	4	188
Giardiasis	1	19	2	157	3	176
Amebiasis	2	14	1	25	3	39
	95	6,564	35	39,810	130	46,374

* One gastroenteritis outbreak also included 7 cases infectious hepatitis.

** One gastroenteritis outbreak was preceded by outbreak of 38 cases of salmonellosis.

7 cases of infectious hepatitis developed. Two consecutive outbreaks (38 cases of salmonellosis and 93 cases of gastroenteritis) occurred approximately two weeks apart at the same location. For reporting purposes, these are considered as single outbreaks.

Most of the outbreaks are classified as gastroenteritis, 39 outbreaks and 26,546 cases of illness. Gastroenteritis is an inflammation of the stomach and intestinal tract, and the symptoms may include nausea, vomiting and diarrhea. A number of different causative agents, many of which are still unidentified, can be responsible for this condition. An unknown percentage of these infectious agents are felt to be of viral origin. Those illnesses and outbreaks where the above symptoms were exhibited but no specific etiologic agent could be determined have been grouped in this particular entity. These include such illnesses described as "sewage poisoning", unspecified diarrhea, etc. In many of these type outbreaks no attempt was made to isolate the pathogen from the water or via stool samples; or if laboratory analyses were performed, they failed to identify the causative agent.

The most commonly identified pathogen in outbreaks during this period was salmonella, 23 outbreaks. Typhoid

(Salmonella typhi) accounted for 14 of these outbreaks, all in private systems. The 104 cases of typhoid associated with waterborne-disease outbreaks represents about 2.2 percent of the total number of typhoid cases due to all causes reported during the 1961-70 period. Nineteen waterborne outbreaks were attrib.ted to Shigella, the most common serotype being *Shigella sonnei*.

Two agents never before associated with documented waterborne outbreaks in this country appeared during the 1961-70 period, enteropathogenic *E. coli (EEC)* and *Giardia lamblia*. Various serotypes of *EEC* have been implicated as the etiologic agent responsible for disease in newborn infants, usually the result of cross contamination in nurseries. Now, there are several well-documented outbreaks of *EEC* (serotypes O111:B4 and O124:B27) associated with adult waterborne disease(10,11).

Giardia lamblia is a flagellated protozoan responsible for giardiasis. The three outbreaks of giardiasis occurred in resort or recreational areas.

Another protozoal infection sometimes transmitted by the waterborne route is amebiasis or amebic dysentery which occurred in three outbreaks. The etiologic agent for this disease is *Entamoeba histolytica*, an ameba.

There were five outbreaks attributed to pesticide poisoning; two were related to termite control operations where pesticide was pumped into the ground. With

the rising concern for ecology, the more acutely toxic organo-phosphate compounds may become increasingly important as causes of waterborne disease, as they are substituted for the more persistant chlorinated hydrocarbons.

A disease related to the nitrate content of drinking water, methemoglobinemia, is not included in the tabulation. This disease is not reportable and its incidence is not known. Three investigators were motivated in the past ten years to describe cases that came to their attention: One(12)occurred to an infant using a public water supply in Brighton, Colorado (60 mg/l Nitrate) and another(13) infant became ill from using a private well on a Texas farm (77 mg/l Nitrate). The third report(14) concerns an adult with a kidney condition who was using home dialysis with water from a private well (417mg/l Nitrate).

Hospital infections have been related to the bacterial flora of water supply even though the water met the coliform limits of the Drinking Water Standards(15). This problem area has not been reviewed in this survey, but two instances are mentioned in the hope of stimulating interest in this problem. A report in the New Yorker Magazine(16) related how Pseudomonas organisms from the

aerating cap on a faucet resulted in an epidemic in a premature-baby nursery. Another report(17) associated Flavobacteria from water used in a hospital to systemic infections following extensive open-heart surgery.

As was previously noted in Figure 2, only 56 percent of the waterborne outbreaks tabulated for the period 1961-70 had been officially reported. For the remaining outbreaks, data were obtained from sources other than NCDC and are considered to be non-reported outbreaks. A further analysis was conducted of the reported and non-reported outbreaks for the previous ten years to determine if system size, type of system, and type of disease had any bearing on whether or not an outbreak was reported.

The outbreaks most frequently found not to have been reported to NCDC were chemical poisonings via the drinking water. Chemical poisonings are not required to be reported and apparently are rarely brought to the attention of NCDC because they are not of an infectious nature; however, it should be realized that due to the increased use of chemicals in today's society more emphasis must be placed on their effect to human health, long-term as well as acute.

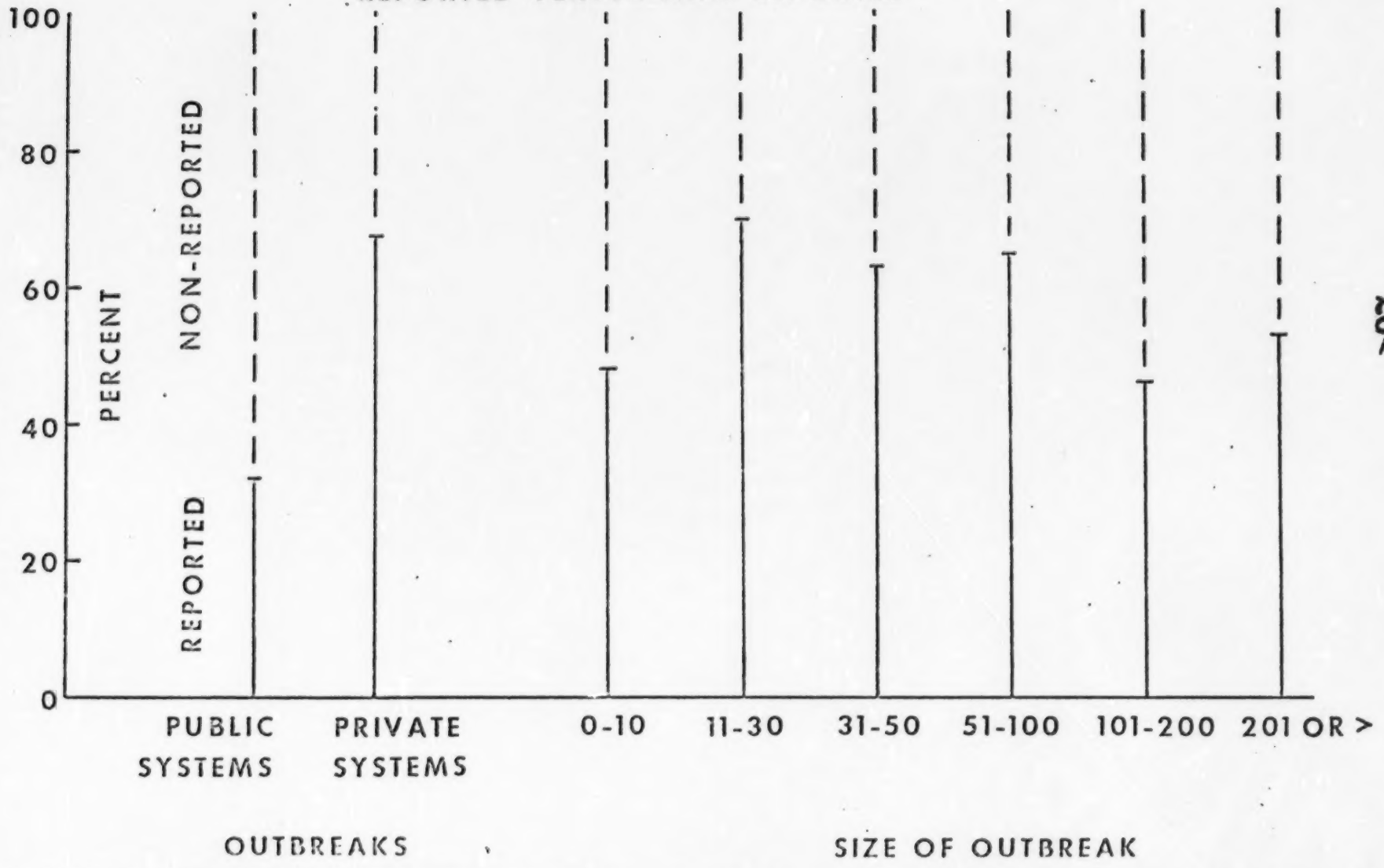
Waterborne outbreaks of shigellosis, typhoid, enteropathogenic *E. coli*, amebiasis, and giardiasis were found to have almost always been reported to NCDC. These are specific diseases requiring laboratory confirmation to identify the etiologic agent. Several are reportable diseases. A specific disease found to have been poorly reported was salmonellosis; 67 percent of the waterborne outbreaks of this disease were non-reported. Just why this occurred is not known.

It was expected to find that many of the waterborne outbreaks of gastroenteritis would be non-reported, primarily because of the nature of this illness. It was surprising to find, however, that the reporting for hepatitis was quite similar to reporting for gastroenteritis; only about half of the outbreaks tabulated had been reported. Viral hepatitis is a reportable disease, but it is anticipated that the cause of the outbreak, which must be established by epidemiologic investigations, is not always reported.

It was thought that larger outbreaks would more likely be reported than smaller outbreaks, but this was not found to be the case. The data in Figure 3 do not indicate any better reporting for the larger outbreaks, and it would appear that there is little, if any relationship between the size of an outbreak and

WATERBORNE-DISEASE OUTBREAKS BY TYPE OF SYSTEM AND SIZE OF OUTBREAK 1961-70

REPORTED VERSUS NON-REPORTED



20<

whether or not it is reported.

Reported and non-reported outbreaks were compared between public systems and private systems. This information is presented also in Figure 3. It was rather surprising to find about twice as many reported outbreaks in the private systems. Of the outbreaks tabulated for public systems during the period 1961-70, only one-third had been officially reported. The high percentage of non-reported outbreaks in the public systems is due, of course, to the definition of "reported" and emphasizes the fact that many outbreaks are investigated but are not brought to the attention of NCDC. This, however, does not fully explain the difference found in reporting between public and private systems. In polling the state health department officials, a lack of information and poor communication was occasionally noted among the various agencies within a state. This may offer a partial explanation as to why overall reporting was generally poor.

Waterborne Disease 1946-1970.

The primary objective of this paper is to review the outbreaks and their causes so that a knowledge of the problem can be gained and used to prevent the recurrence of waterborne disease. It was felt that a more comprehensive analysis would result if data obtained over a longer time

period were examined. Comparable data available for the past 25 years were used; outbreaks tabulated for the current period 1961-70 were combined with those of the previous review period 1946-60. The data for each of these periods were generally obtained in similar fashion and information pertaining to each individual outbreak during the earlier period was readily available.

Table 4 presents the waterborne disease data over the 25-year period. The table includes a slight revision of the 1946-60 data(6). During the 25-year period 1946-70, there were 356 known waterborne outbreaks. These outbreaks resulted in 72,358 illnesses and 30 deaths. As was the case in both periods, the four major categories of illness, in terms of number of outbreaks and cases, are gastroenteritis, typhoid, infectious hepatitis, and shigellosis. As anticipated, most of the outbreaks for the total period were classified as gastroenteritis.

Outbreaks of viral hepatitis over the previous 25-year period have clearly been demonstrated to be waterborne and it is now generally accepted that infectious hepatitis is a waterborne disease. The most frequent mode of spread, however, is by person-to-person contact. A comparison of the hepatitis cases occurring in waterborne outbreaks and the total number of reported cases of the

Table 4

WATERBORNE-DISEASE OUTBREAKS 1946-70
BY TYPE OF ILLNESS AND SYSTEM

ILLNESS	PRIVATE SYSTEMS		PUBLIC SYSTEMS		TOTAL	
	OUTBREAKS	CASES	OUTBREAKS	CASES	OUTBREAKS	CASES
GASTROENTERITIS	121	8,970	57	36,285	178	45,255
TYPHOID	47	507	6	103	53	610
INFECTIOUS HEPATITIS	36	1,094	17*	739	53	1,833
SHIGELLOSIS	23	1,616	10	5,784	33	7,400
SALMONELLOSIS	7**	118	6	16,612	13	16,730
CHEMICAL POISONING	8	52	4	8	12	60
AMEBIASIS	4	50	1	25	5	75
ENTEROPATHOGENIC *E. coli*	4	188	-	-	4	188
GIARDIASIS	1	19	2	157	3	176
LEPTOSPIROSIS	-	-	1	9	1	9
TULAREMIA	2	6	-	-	2	6
POLIOMYELITIS	-	-	1	16	1	16
TOTALS	253	12,620	105	59,738	358	72,358

* ONE GASTROENTERITIS OUTBREAK ALSO INCLUDED 7 CASES INFECTIOUS HEPATITIS.

** ONE GASTROENTERITIS OUTBREAK WAS PRECEDED BY OUTBREAK OF 38 CASES OF SALMONELLOSIS.

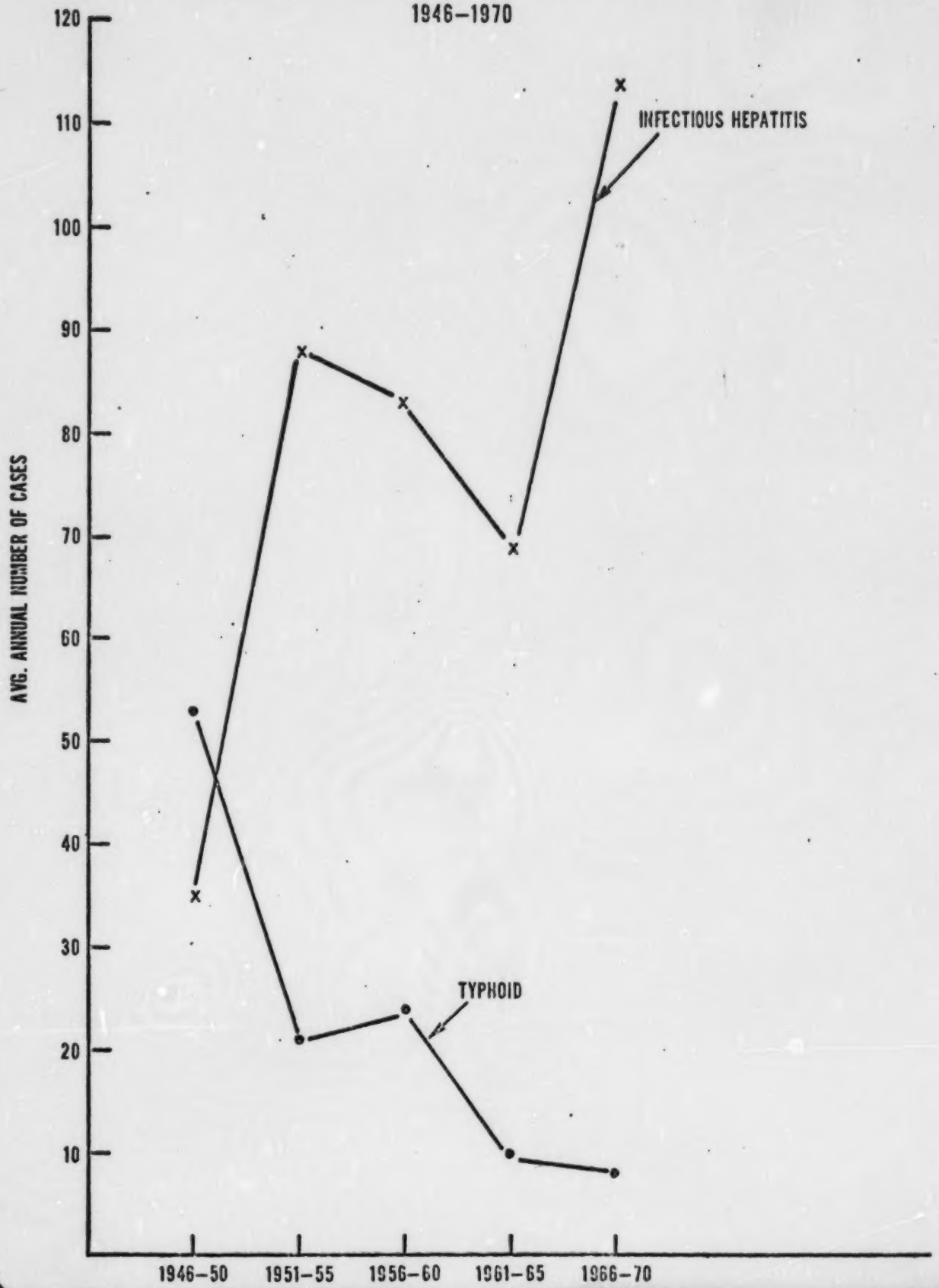
disease was made for two periods. About 0.3 percent of the hepatitis cases reported during 1952-60 were associated with waterborne outbreaks; about the same proportion, 0.2 percent, of the cases reported during 1961-70 were associated with waterborne outbreaks. Viral hepatitis did not become a reportable disease on national basis until 1952 and up to 1965 was reported as a single entity. After that year, cases were reported as serum or infectious hepatitis.

The deaths which were attributed to waterborne outbreaks during the 25-year period were associated with chemical poisoning (ten deaths), typhoid (eight), shigellosis (six), amebiasis (four), enteropathogenic *E. coli* (four), salmonellosis (three), infectious hepatitis (one).

Hepatitis and Typhoid

A closer look at both infectious hepatitis and typhoid occurring in waterborne outbreaks during 1946-70 is presented in Figure 4. These data indicate a decline in the significance of typhoid as a waterborne disease but an increase in the relative importance of infectious hepatitis. Over the 25-year period, the average annual

AVERAGE ANNUAL NUMBER OF TYPHOID AND INFECTIOUS HEPATITIS CASES OCCURRING IN WATERBORNE OUTBREAKS 1946–1970



number of typhoid cases occurring in waterborne outbreaks decreased from 53 to 8; infectious hepatitis increased from 35 to 114. The increase noted for infectious hepatitis was not because more infectious hepatitis outbreaks had occurred in public systems. There were 8 waterborne outbreaks of infectious hepatitis and 475 cases in public systems during 1951-60; 8 outbreaks and 239 cases during 1961-70. The peak year in the long-term cycle for viral hepatitis for cases occurring from all causes was 1961.

The cases of infectious hepatitis occurring in waterborne outbreaks during the 25-year period were examined by source of contamination and type of system. These data are presented in Table 5. The majority of infectious hepatitis outbreaks in public systems occurred as the result of contamination of the distribution system, primarily through cross-connections and back-siphonage; for private systems, contamination of untreated ground water supplies was the important factor.

Table 5

CASES OF INFECTIOUS HEPATITIS OCCURRING IN WATERBORNE OUTBREAKS 1946-70 BY SOURCE OF CONTAMINATION

Cause	Public Systems		Private Systems	
	Outbreaks	Cases	Outbreaks	Cases
1. Use of Untreated Surface Water	1*	189	7	135
2. Use of Untreated Ground Water	2	20	23	737
3. Inadequate or Interruption of Disinfection	1	83	3	152
4. Contamination Through Distribution System	10	295	1	47
5. Insufficient Data	3	152	2	23

*This outbreak was attributed to contamination of two auxiliary sources, one a stream and the other a spring.

Waterborne Illness Rate

Most of the outbreaks (71 percent) occur in private supplies, but most of the cases of waterborne disease (83 percent) occur in public supplies. This, of course, is related to the number of systems and number of people served by the systems. A comparison can be made by considering the population served on a regular basis by private and public systems. During the period 1946-60, there were 1.1 waterborne illnesses per 100,000 people per year with about an equal rate for private (0.9) and public (1.1) users. In the last ten years, 1961-70, the rate was 2.3 waterborne illnesses per 100,000 persons per year, but the rate in public systems (2.6) was twice that of private systems (1.3). This is because there were several large outbreaks in the past ten years: Riverside, California (16,000 cases); Gainesville, Florida (16,000 cases); Madera, California (2,500); Voorheesville, New York (1,500).

Regulatory agencies that must protect the public's health have to set priorities because there are not enough resources to do everything that needs to be done. How to arrive at these priorities is most difficult. The private systems have most of the outbreaks but the public systems have most of the cases. Because of the efficiency of distribution systems in disseminating infectious

or chemical agents, there is always the possibility of a medical disaster when something does go wrong in public systems.

Seasonal Variation

The distribution of outbreaks by months for the period 1946-70 is shown in Table 6. It was found that the outbreaks associated with public systems had a relatively uniform distribution through the year, which tends to indicate somewhat of a random occurrence of outbreaks in public systems. In contrast, the outbreaks associated with private systems were found to peak during the summer months. Almost one-half of the outbreaks in private systems occurred in June, July and August. This might indicate that there is increased contamination of these supplies during this period, or if it is assumed that the supplies are always contaminated, it might indicate use by more susceptible individuals during the period.

A further analysis of 241 of the 252 outbreaks associated with private systems was accomplished. Although occasionally the data were somewhat meager, the outbreaks were classified in the groups noted in Table 6: (1) Outbreaks that apparently occurred among individuals who normally used the supplies; (2) Outbreaks in schools

Table 6

SEASONAL DISTRIBUTION

WATERBORNE-DISEASE OUTBREAKS 1946-70

MONTH	PUBLIC SYSTEMS PERCENT	PRIVATE SYSTEMS PERCENT	PRIVATE SYSTEMS AFFECTED POPULATION* 1	2	3	4
JAN.	6.0	5.8	8	1	5	0
FEB.	9.1	2.9	4	0	2	1
MAR.	8.1	3.7	8	0	1	0
APR.	10.1	6.6	10	1	5	0
MAY	9.1	7.8	7	3	7	1
JUN.	6.0	10.7	11	2	13	0
JUL.	9.1	24.3	17	1	40	0
AUG.	9.1	14.8	8	1	27	0
SEP.	8.1	9.9	9	2	13	0
OCT.	7.1	8.2	15	4	1	0
NOV.	7.1	2.0	5	0	0	0
DEC.	11.1	3.3	4	1	3	0
TOTALS	100.	100.	106	16	117	2

* 1 - Habitual Users
  2 = School
  3 = Visitor
  4 = Unclassified

or institutions; (3) Outbreaks that occurred among individuals who did not use the supplies on a regular basis, such as restaurant patrons, campers, travelers, etc. Approximately 49 percent of the outbreaks in private systems affected a population comprised primarily of visitors, and of these outbreaks, 68 percent occurred during the three summer months. This would indicate that more susceptible individuals are using water that is always contaminated. There was only a slight concentration of outbreaks in the summer months among the habitual users of private systems; 34 percent versus the 27 percent that would be expected in a random distribution. This tends to attach less significance to increased contamination of these supplies during the summer months.

Causes of Outbreaks

The 25-year period covered in this review, 1946-70, involves 356 waterborne outbreaks and 72,358 cases of illness. A detailed tabulation of the causes of these outbreaks is presented in Table 7.

It was difficult in some cases to identify the specific cause of an outbreak because of the lack of

Reproduced from best available copy.

Table 7

INCIDENCE OF WATERBORNE DISEASE IN THE UNITED STATES, 1946-70, BY SOURCE OF CONTAMINATION

	PRIVATE		PUBLIC		ALL SYSTEMS	
	OUTBREAKS	CASES	OUTBREAKS	CASES	OUTBREAKS	CASES
SOURCE:						
A. SURFACE WATER (UNTREATED)						
1. USE OF UNTREATED SURFACE WATER AS USUAL SOURCE						
A. CONTAMINATION ON WATERSHED	7*	494*	4	327	11	821
B. OVERFLOW OF SEWAGE OR OUTFALL NEAR SOURCE	3	42	-	-	3	42
C. FLOODING	1	77	-	-	1	77
D. CONTAMINATION OF RAW WATER TRANSMISSION LINE	-	-	-	-	-	-
E. DEAD ANIMALS IN RESERVOIR	1	100	-	-	1	100
F. SOURCE OF CONTAMINATION NOT DETERMINED	8	158	4	564	12	722
2. USE OF CONTAMINATED SURFACE WATER FOR SUPPLEMENTARY SOURCE	2	90	4	1,043	6	1,133
TOTAL	22	961	12	1,934	34	2,895
B. GROUND WATER (UNTREATED)						
1. IMPROPER CONSTRUCTION OR LOCATION OF WELL OR SPRING						
A. SURFACE CONTAMINATION NEARBY	21*	640*	1	2,500	22	3,140
B. OVERFLOW OR SEEPAGE OF SEWAGE	49	2,779	4	531	53	3,310
C. SEEPAGE FROM ABANDONED WELL	1	50	-	-	1	50
D. CONTAMINATION THROUGH SUCTION PIPE	-	-	-	-	-	-
E. SOURCE OF CONTAMINATION NOT DETERMINED	8	235	1	400	9	635
2. FLOODING	4	66	3	4,400	7	4,466
3. CONTAMINATION THROUGH CREVICED LIMESTONE OR FISSURED ROCK	10	555	1	70	11	625
4. CHEMICAL OR PESTICIDE CONTAMINATION	4	17	-	-	4	17
5. DATA INSUFFICIENT TO CLASSIFY	46	2,001	3	16,350	49	18,351
TOTAL	143	6,343	13	24,251	156	30,594
C. GROUND WATER (CHLORINATION ONLY)						
1. SUFFICIENT CONTAMINATION OF SOURCE TO OVERWHELM TREATMENT PROVIDED						
A. OVERFLOW OR SEEPAGE OF SEWAGE	-	-	3	16,273	3	16,273
B. FLOODING	-	-	1	600	1	600
C. CONTAMINATION OF RAW WATER TRANSMISSION LINE OR SUCTION PIPE	1	31	-	-	1	31
TOTAL	1	31	4	16,873	5	16,904
TREATMENT:						
A. INADEQUATE CHLORINATION WHEN ONLY TREATMENT						
1. SURFACE WATER SOURCE	11	1,850	5	2,736	16	4,586
2. GROUND WATER SOURCE (SEE ALSO SOURCE, C.1)	7	227	1	180	8	407
B. INTERRUPTION OF CHLORINATION WHEN ONLY TREATMENT	7	235	5	2,792	12	3,027
C. INADEQUATE CHLORINATION WITH OTHER TREATMENT	-	-	7	6,155	7	6,155
D. INADEQUATE CONTROL OF FILTRATION AND ALLIED TREATMENT	-	-	1	34	1	34
TOTAL	25	2,312	19	11,877	44	14,189
DISTRIBUTION:						
A. CONTAMINATION OF MAINS DURING CONSTRUCTION OR REPAIR	1	5	7	1,245	8	1,250
B. WATER MAIN AND SEWER IN SAME TRENCH OR INADEQUATELY SEPARATED	-	-	2	84	2	84
C. IMPROPER OR NO DISINFECTION OF MAINS OR PLUMBING	-	-	2	60	2	60
D. CROSS-CONNECTION	8	319	14	1,752	22	2,071
E. BACKSIPHONAGE	9	486	16	785	25	1,271
TOTAL	18	810	41	3,926	59	4,736
STORAGE:						
A. CONTAMINATION OF CISTERN	2	122	-	-	2	122
B. CONTAMINATION OF DISTRIBUTION STORAGE FACILITY	-	-	-	-	-	-
C. CONTAMINATION OF INDIVIDUAL STORAGE FACILITY	-	-	1	31	1	31
D. IMPROPER OR NO DISINFECTION OF NEW STORAGE FACILITY	-	-	1	58	1	58
TOTAL	2	122	2	89	4	58
MISCELLANEOUS:						
A. USE OF WATER NOT INTENDED FOR DRINKING	16	349	1	30	17	359
B. CONTAMINATED BUCKETS	3	24	1	9	4	33
C. CONTAMINATED DRINKING FOUNTAINS	1*	19	2	48	3	67
D. DELIBERATE CONTAMINATION	1	10	-	-	1	10
E. CONTAMINATED ICE	1	700	-	-	1	700
F. INSUFFICIENT DATA	20	1,160	9	721	29	1,881
TOTAL	42	2,262	13	788	55	3,050
GRAND TOTAL	253*	12,843*	104	59,738	357	72,579

*ONE OUTBREAK OF 221 CASES COUNTED TWICE IN LISTING BECAUSE OF CONTAMINATION OF TWO SEPARATE SOURCES.

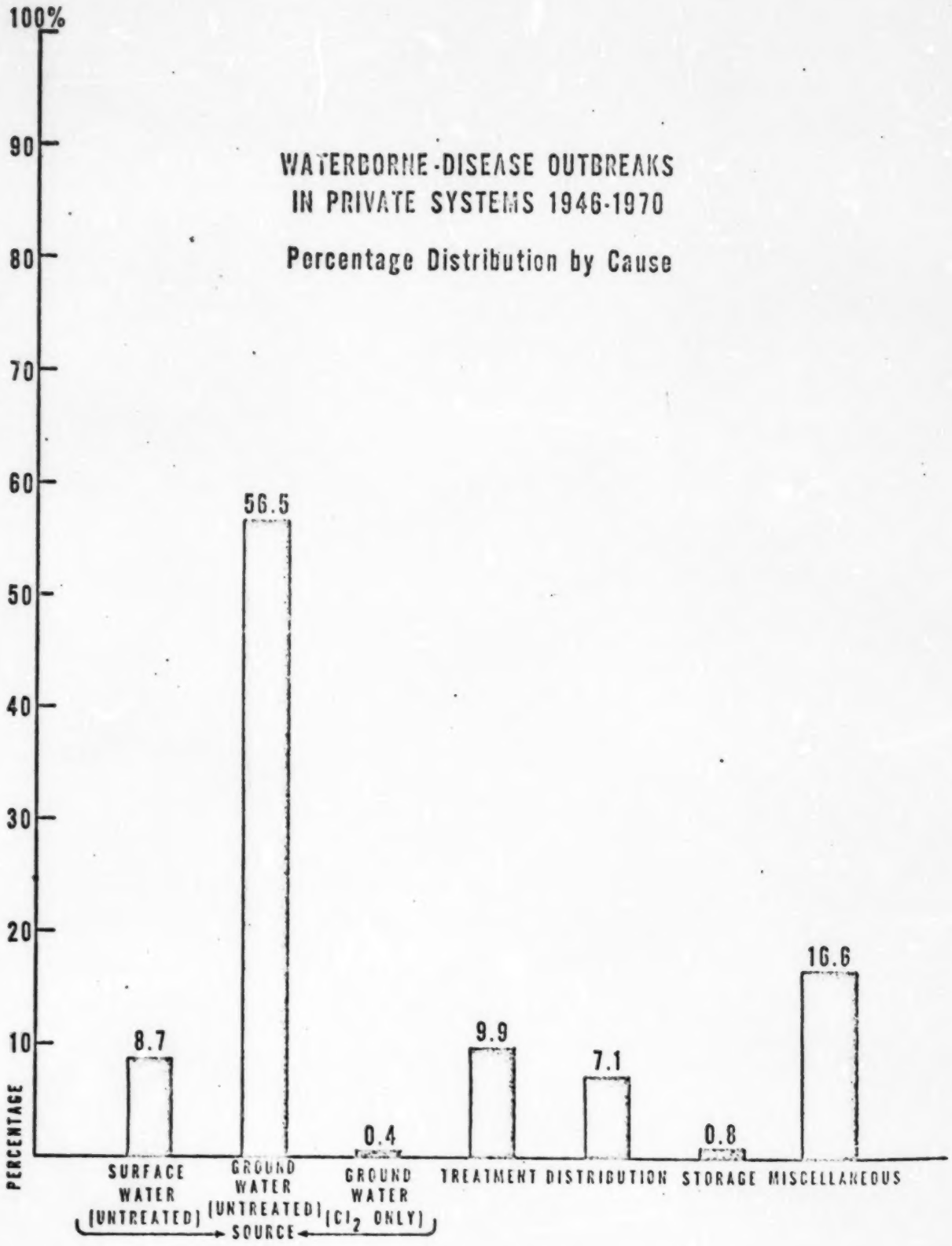
information. Twenty-nine outbreaks were included in the miscellaneous category because of insufficient data, and there were 49 outbreaks associated with untreated ground water systems where a specific cause had not been established. In addition, several outbreaks were identified with the use of untreated ground or surface water that was contaminated but the source of contamination was not determined. This further emphasizes the need for better investigation and reporting if we are to understand the problem and take corrective action.

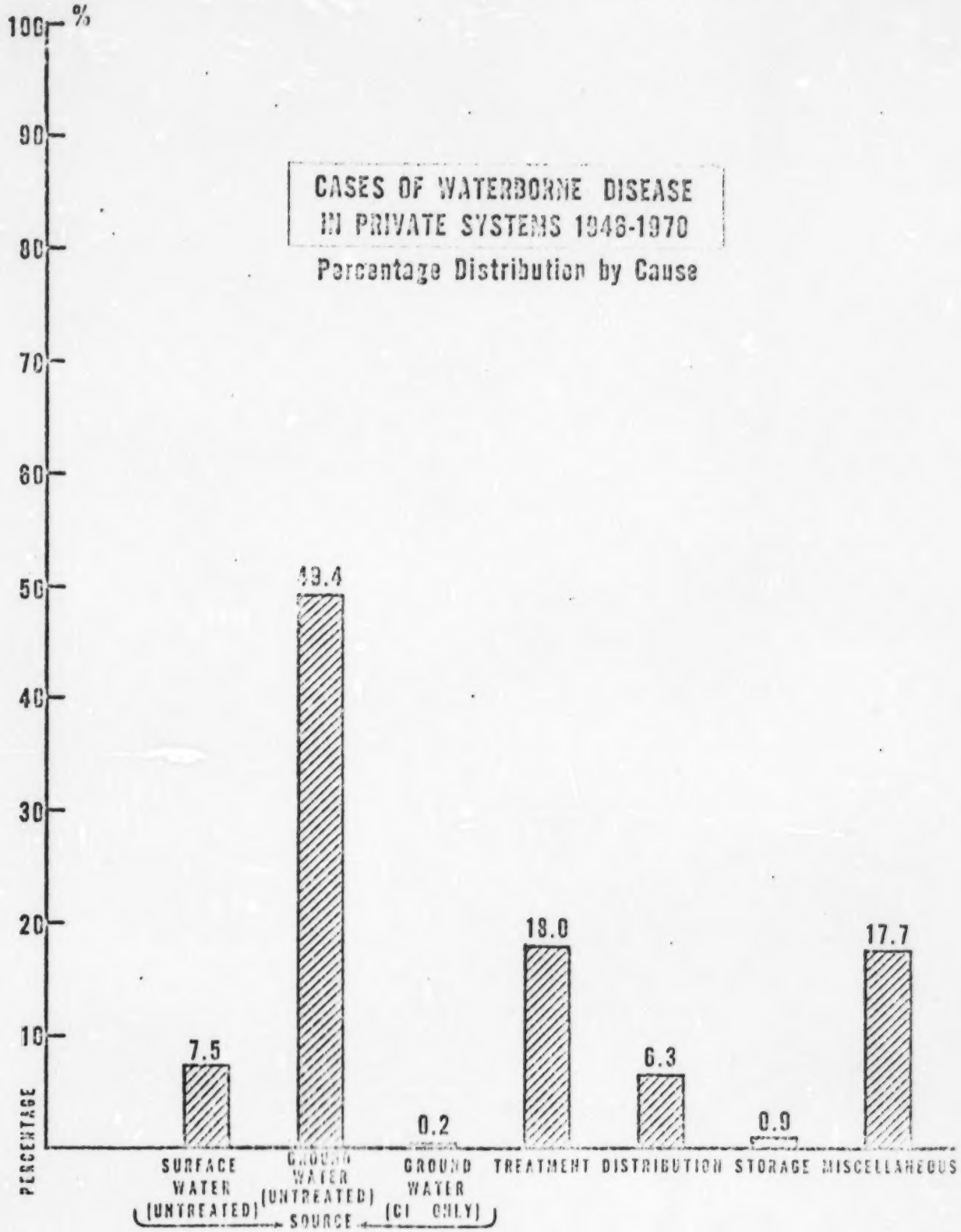
In classifying causes for ground water supplies where chlorination was the only treatment provided, a distinction was made as to whether the outbreak was primarily related to contamination of the source or a deficiency in treatment. Naturally, if an outbreak occurred in such a system and was due to source contamination, a deficiency also existed in the treatment provided, and so the difference is rather academic. Water systems using wells usually depend on using a relatively good quality water and often times chlorination is provided primarily to offer protection from possible contamination of distribution facilities. In these cases, if an unexpected contamination of the source completely overwhelmed the disinfection normally provided, it was

decided to classify the outbreak under source contamination. Outbreaks classified under treatment deficiencies were those that occurred in systems using a source which was known to be frequently or intermittently contaminated and chlorination was necessary at all times to insure potability of the water. In some of these type outbreaks, chlorine dosages had been reduced below prescribed levels or no attention was given to maintaining a proper residual. It was felt that in such instances the cause was primarily related to a deficiency in treatment because contamination of the source was known and greater emphasis should have been placed on treatment if use of the source continued.

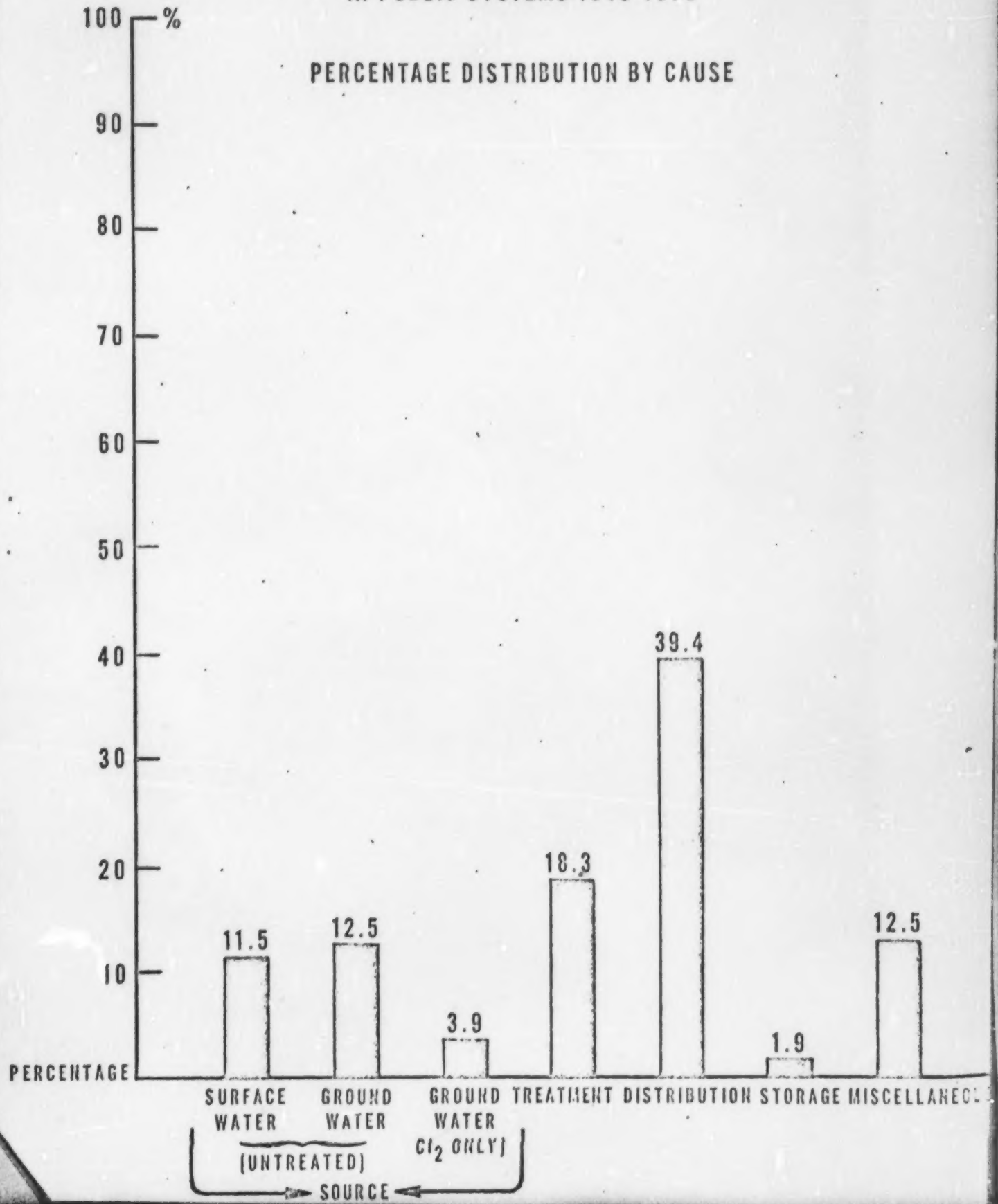
A more clear and concise picture of the causes of outbreaks is contained in Figures 5-8. These figures offer a graphical presentation of the percentage distribution of both outbreaks and cases of illness according to the major categories of causes noted in Table 7. Figure 5 is concerned with outbreaks in private systems; Figure 6 with cases of illness in private systems; Figure 7, outbreaks in public systems; Figure 8, cases of illness in public systems.

In private systems, quite similar results are obtained when outbreaks and cases of illness are analyzed.

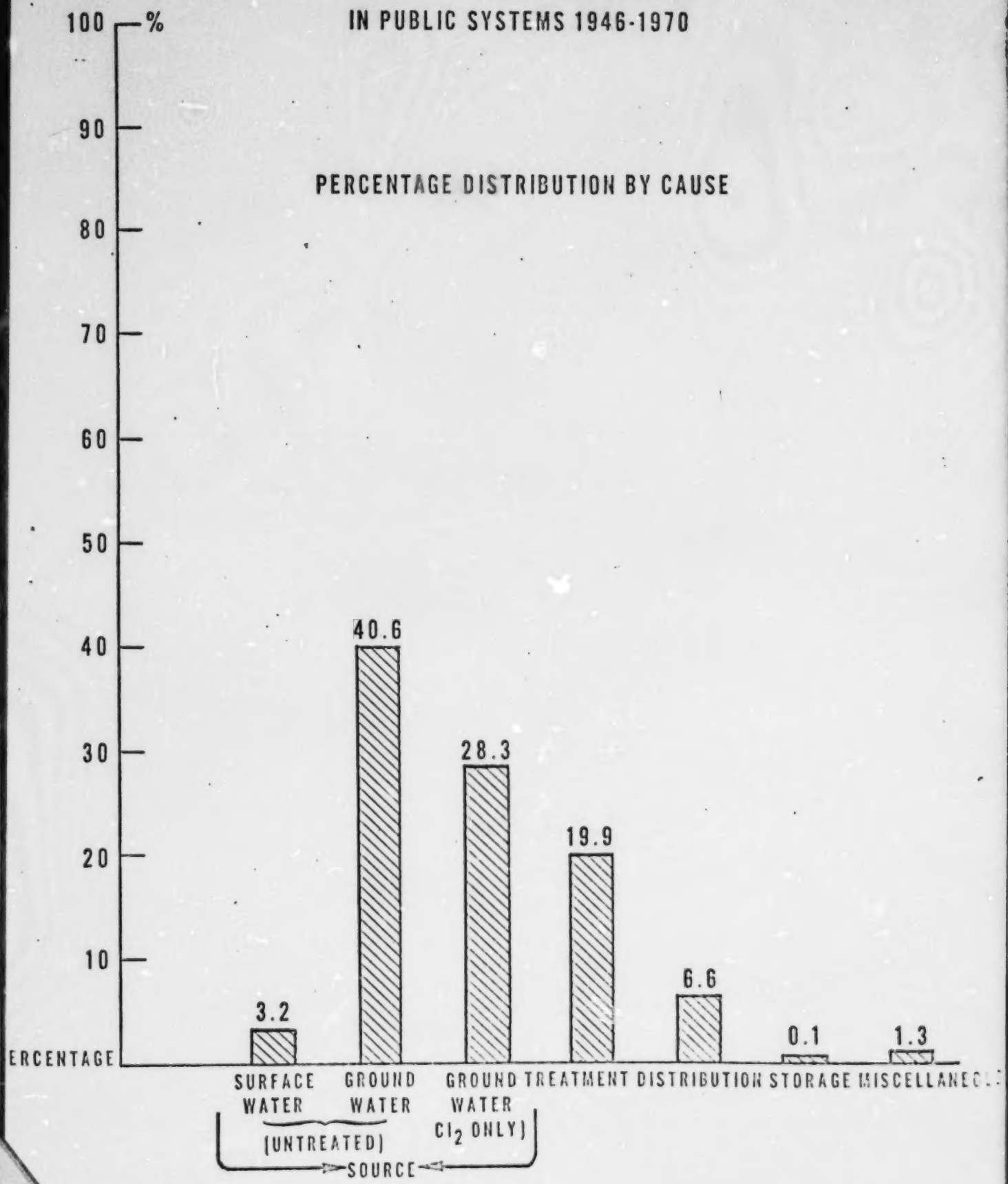

WATERBORNE-DISEASE OUTBREAKS
IN PRIVATE SYSTEMS 1946-1970
Percentage Distribution by Cause
100%
90
80
70
60
50
40
30
20
10
PERCENTAGE
8.7
56.5
0.4
9.9
7.1
0.8
16.6
SURFACE WATER (UNTREATED)
GROUND WATER (UNTREATED)
GROUND WATER (Cl_2 ONLY)
SOURCE
TREATMENT
DISTRIBUTION
STORAGE
MISCELLANEOUS


CASES OF WATERBORNE DISEASE
IN PRIVATE SYSTEMS 1946-1970
Percentage Distribution by Cause
100
%
90
80
70
60
50
40
30
20
10
PERCENTAGE
7.5
49.4
0.2
18.0
6.3
0.9
17.7
SURFACE WATER (UNTREATED)
GROUND WATER (UNTREATED)
GROUND WATER (Cl ONLY)
SOURCE
TREATMENT
DISTRIBUTION
STORAGE
MISCELLANEOUS

WATERBORNE-DISEASE OUTBREAKS IN PUBLIC SYSTEMS 1946-1970



CASES OF WATERBORNE DISEASE IN PUBLIC SYSTEMS 1946-1970



The major problem in these systems is the use of untreated ground water. About 57 percent of the outbreaks and 49 percent of the cases were found to have been related to this particular cause. Because of the unsatisfactory construction and location of wells, all kinds of contamination have occurred. These have ranged from the usual problem associated with wells in limestone areas to overflowing sewage, flooding, and chemical contamination.

The major cause of outbreaks in public systems is contamination of the distribution system, primarily cross-connections and back-siphonage. However, when cases of illness are considered the picture changes. Outbreaks resulting from contamination of the distribution system are usually quite contained and few illnesses result (Figure 8). But when there is contamination of the source or a breakdown in treatment, many illnesses result. When cases of illness are considered, then the major problems are source contamination and treatment deficiencies. About 46 percent of the outbreaks in public systems were found to have been related to these two particular causes; 92 percent of the cases of illness in public systems occurred as the result of source and treatment deficienties.

Distribution by Population, Public Systems

Table 8 relates the distribution of waterborne outbreaks and cases of illness in public systems to

Table 8

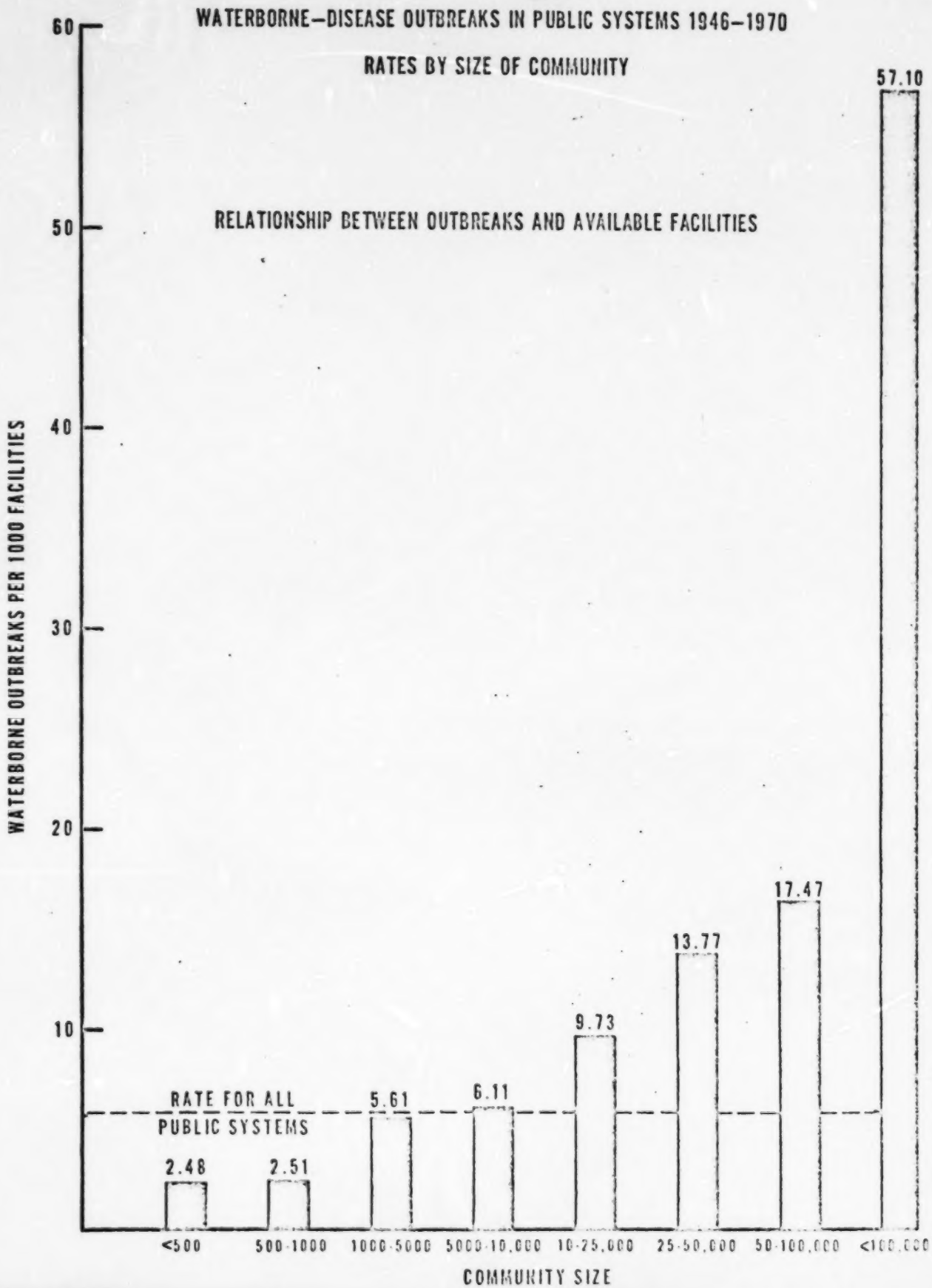
DISTRIBUTION OF WATERBORNE DISEASE IN PUBLIC SYSTEMS

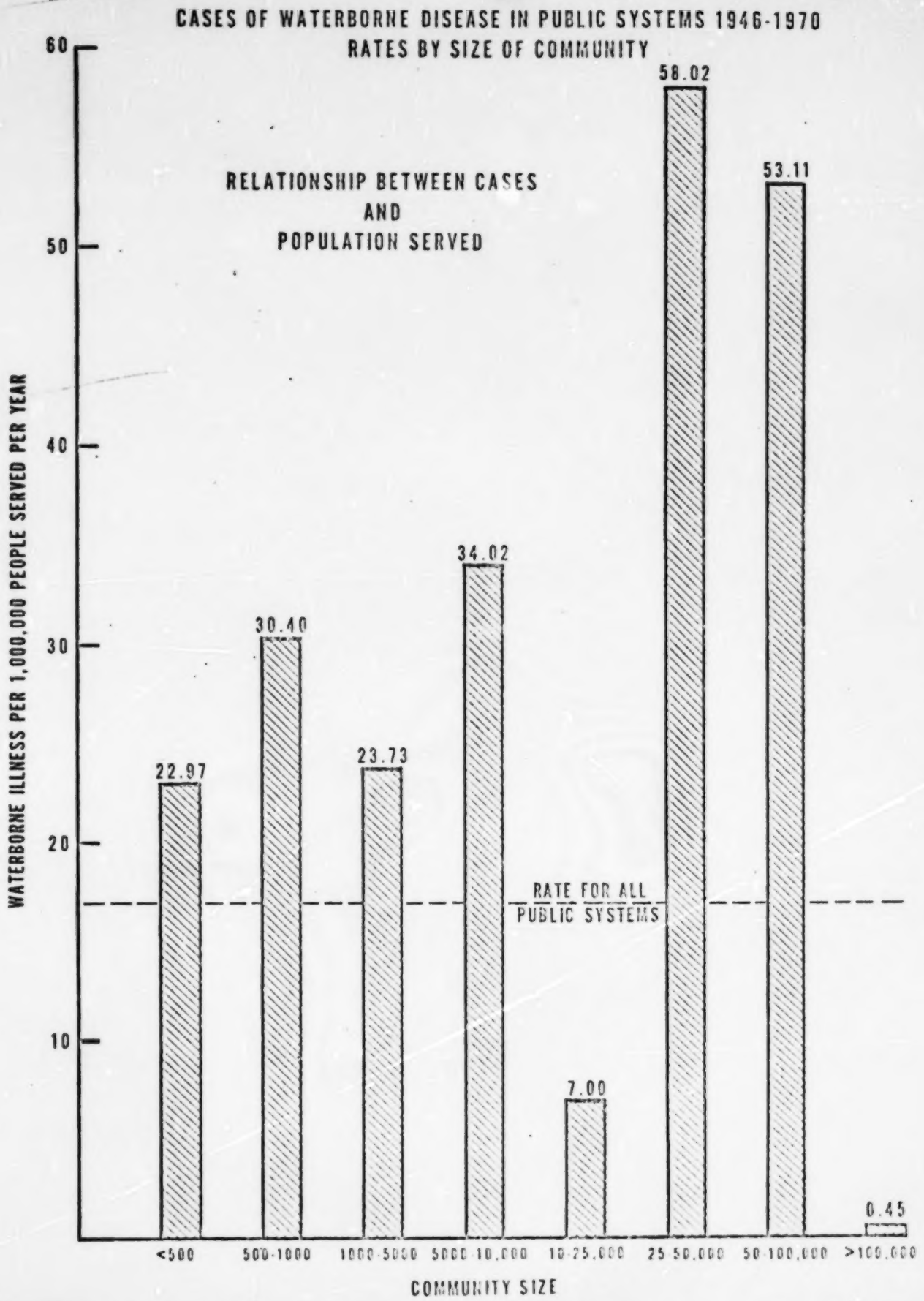
BY SIZE OF COMMUNITY SERVED, 1946-70

	NO. OF OUTBREAKS	NO. OF CASES	WATERBORNE OUTBREAKS PER 1,000 FACILITIES	WATERBORNE DISEASE ILLNESS PER 1,000,000 PEOPLE SERVED PER YEAR
<500	13	998	2.48	22.97
500-1,000	10	2,409	2.51	30.40
1,000-5,000	33	8,732	5.61	23.73
5,000-10,000	8	8,419	6.11	34.02
10,000-25,000	10	2.725	9.73	7.00
25,000-50,000	6	18,812	13.77	58.02
50,000-100,000	4	16,725	17.47	53.11
>100,000	16	779	57.10	0.45
Unknown	4	139		
TOTAL	104	59,738	5.66	17.05

community size. For comparative purposes, the number of public facilities and population served by these facilities were used to calculate rates for each community size. The number of facilities and population figures are weighed estimates based on data from the 1958 and 1963 Inventory of Municipal Water Supplies(18,19). To facilitate the comparison, a graphical presentation of these data is contained in Figures 9 and 10. Figure 9 compares outbreaks and facilities; Figure 10, illness and population served.

The increasing rate of outbreaks with size of systems supports the requirements on sampling frequency contained in the Drinking Water Standards. The larger systems, in general, are more complex and contain more opportunities for cross-connections to occur. More samples are needed to provide surveillance of these increased opportunities for contamination, and positive bacteriological results must be followed up because they may indicate the occurrence of an operating cross-connection that has not yet resulted in an outbreak.


WATERBORNE—DISEASE OUTBREAKS IN PUBLIC SYSTEMS 1946—1970
RATES BY SIZE OF COMMUNITY
RELATIONSHIP BETWEEN OUTBREAKS AND AVAILABLE FACILITIES
WATERBORNE OUTBREAKS PER 1000 FACILITIES
60
50
40
30
20
10
57.10
17.47
13.77
9.73
6.11
5.61
RATE FOR ALL PUBLIC SYSTEMS
2.48
2.51
<500
500-1000
1000-5000
5000-10,000
10-25,000
25-50,000
50-100,000
<100,000
COMMUNITY SIZE


CASES OF WATERBORNE DISEASE IN PUBLIC SYSTEMS 1946-1970
RATES BY SIZE OF COMMUNITY
RELATIONSHIP BETWEEN CASES
AND
POPULATION SERVED
WATERBORNE ILLNESS PER 1,000,000 PEOPLE SERVED PER YEAR
60
50
40
30
20
10
22.97
30.40
23.73
34.02
7.00
58.02
53.11
0.45
RATE FOR ALL
PUBLIC SYSTEMS
<500
500-1000
1000-5000
5000-10,000
10-25,000
25-50,000
50-100,000
>100,000
COMMUNITY SIZE

Almost half of the population using public facilities during the 25-year period obtained water from systems serving more than 100,000 people. These large systems constitute about 1.5 percent of the public facilities in the U.S. A disproportionate number of outbreaks occurred in systems of this size, but the outbreaks were small in terms of cases of illness. The outbreak rate for these large utilities was 57.10 waterborne outbreaks per 1,000 facilities. However, of outbreaks because the majority were related to cross-connections and affected only a small number of people, the waterborne disease illness rate per 1,000,000 people served per year was 0.45.

To get an idea of which size community has the greatest problem, both outbreaks and illnesses must be considered Communities of 25,000 to 50,000 and 50,000 to 100,000 had more than their share of waterborne disease. The systems

of these two size classifications supply water to about 20 percent of the total population served by public systems. Waterborne disease illness rates for these two sized communities was about three times the rate exhibited by public systems as a whole. Similarly, these communities had about three times the number of outbreaks that occurred in public systems as a whole.

Source and Treatment, Public Systems

Distribution-related outbreaks can occur in any system, but as previously noted these type outbreaks are usually quite contained and result in few illnesses. The larger outbreaks have been related to source and treatment deficiencies. During the 25-year period, public systems had 48 waterborne outbreaks and 54,935 cases of illness that were attributed to either source contamination or inadequate treatment. These two aspects were examined in detail because of their relative importance in the prevention of waterborne disease in public systems. The distribution of these outbreaks by source and treatment is presented in Table 9; cases of illness by source and treatment in Table 10.

These 48 outbreaks in public systems represent an overall rate of 2.61 outbreaks per 1000 public facilities. An indication of the type system(s) most susceptible to outbreaks can be obtained by comparing

Table 9

DISTRIBUTION OF 48 WATERBORNE OUTBREAKS ASSOCIATED WITH PUBLIC SYSTEMS BY SOURCE AND TREATMENT AND OUTBREAK RATE* FOR FACILITIES OBTAINING AND TREATING WATER THAT WAY 1946-70(18,19)

WATER	GROUND WATER		SURFACE WATER		COMBINED SOURCE		TOTAL	
SERVED	OUTBREAKS	RATE	OUTBREAKS	RATE	OUTBREAKS	RATE	OUTBREAKS	RATE
UNTREATED	11	1.48	4	14.79	6	59.52	21	2.69
TREATED	8	1.21	12	3.84	2	2.76	22	2.10
BOTH	-	-	1	-	4	71.94	5	49.80
TOTAL	19	1.35	17	5.00	12	13.98	48	2.61

*Waterborne Outbreaks per 1,0) Facilities.

Table 10

DISTRIBUTION OF 54,935 CASES OF WATERBORNE DISEASE ASSOCIATED WITH PUBLIC SYSTEMS BY SOURCE AND TREATMENT, AND WATERBORNE ILLNESS RATES* FOR POPULATION USING WATER OBTAINED AND TREATED THAT WAY 1946-70(13,19)

	GROUND WATER		SURFACE WATER		COMBINED SOURCE		TOTAL	
	CASES	RATE	CASES	RATE	CASES	RATE	CASES	RATE
UNTREATED	24,044	84.53	484	73.81	1234	193.39	25,762	86.63
TREATED	19,584	22.64	8992	4.64	206	0.55	28,782	9.03
BOTH	-	-	38	-	353	51.58	391	21.05
TOTAL	43,628	37.52	9514	4.90	1793	4.64	54,935	15.68

*Waterborne illness per 1,000,000 people served per year.

outbreak rates according to source and treatment. Public systems serving untreated surface water have had more than their share of outbreaks; 14.79 outbreaks per 1000 facilities is six times the overall rate. Also having more than their share of outbreaks were the public systems using both ground and surface water sources but providing either no treatment or only partial treatment. These systems had rates about 25 times the overall rate. The use of untreated surface water or combined sources with only partial treatment would suggest that the need for supplying an adequate quantity of water has assumed greater importance than the concern for water quality.

In evaluating this situation to find out where the greatest problem exists and where the primary emphasis must be placed, cases of illness are probably the more important consideration. Illness rates take into account the severity of outbreaks and the prevention of large outbreaks can lower these rates dramatically. The overall waterborne disease illness rate associated with source and treatment deficiencies in public systems was 15.68 per 1,000,000 people served per year. Public systems serving untreated water from any source had more than their share of waterobrne disease - 86.63 per 1,000,000 people served per year. Untreated surface water, which is distributed by public systems to only about 0.1 percent of the population, had an illness

rate 5 times the overall rate. A high illness rate should be expected for people using this type water and there is no reason to allow this situation to exist. Adequate treatment must be provided for these systems. Public systems serving untreated ground water also had a high illness rate, 84.53 per 1,000,000 people served per year. Generally, it is expected that ground water is of good bacteriological quality. However, an illness rate which is about six times the overall rate, indicates that either the quality in many cases is questionable or the source is inadequately protected. More emphasis must be placed on well construction, protection from local contamination, and treatment. If chlorination of all public ground water supplies were required and practiced, it is anticipated that the illness rate could be lowered dramatically to at least that exhibited by the treated ground water supplies, (22.64 per 1,000,000 people).

Case Histories

Several outbreaks during the past ten years illustrate the need for chemical drinking water standards and of course the need to anlayze water to see if it meets standards. A 12-year-old girl from a ranch in Nevada with a serious dermatological problem was having much trouble in finding the cause. At the Stanford Medical Center, a hair sample was analyzed and found to be high in arsenic. The well was checked over a period of several months and the arsenic ranged between 0.5 to 2.75 mg/l. Urine specimens showed the presence of

arsenic in other members of the family. This was the third generation of the family to have used the well, but past arsenic levels are not known(20).

In another situation(21) hair loss, weakened nails, and listlessness affected a Ute Indian Family in Colorado. The family dog also lost its hair. Selenium poisoning was suspected and a well the family had been using for three months was sampled. The selenium concentration was 9. mg/l.

Many of the outbreaks in public systems were found to have been related to cross-connections and back-siphonage. Perhaps the most publicized outbreak of this type occurred among the members of the Holy Cross football team(22,23). Epidemiologic investigation traced the cause of this infectious hepatitis outbreak to submerged irrigation faucets on the practice field. Contributing factors were a hot-humid day, a two-alarm fire, and children playing on the field. Water from the municipal system is supplied to the practice field for both drinking and irrigation purposes. The water line terminates in an equipment house where the drinking fountain is located; several irrigation faucets are located along the course of the line. The low point of the water line is at the drinking faucet, ranging from 2 to 6 feet lower in elevation than the irrigation faucets, which are below ground level. Before the

outbreak occurred, five cases of hepatitis developed in a family living beside the field, one adult and four children. Until onset of the illness, these children, along with others, often played around the irrigation pits, turning on the water and flooding the area. Children had also been seen urinating and defecating in the area. A large fire in town was then felt to be responsible for back-siphonage of surface water around the pits into the water line. Subsequently, the contaminated water was consumed by members of the team using the faucet on the field. Dye tests later confirmed that back-siphonage was possible.

As of January 1, 1971, plumbers must chlorinate the entire water distribution system within new homes and other buildings constructed in Fon Du Lac, Wisconsin, and submit a sample to the local health department for bacteriological analysis prior to accupancy (24). This action was prompted, in part, because of a case of infectious hepatitis that occurred during late 1969. Circumstantial evidence implicated contaminated plumbing in the home as the likely cause of the illness. This single case of infectious hepatitis was not included here as a outbreak, but the city was able to show high bacterial counts from water within the dwelling.

Patrons of a restauraurant in Southeastern Michigan became ill with nausea, vomiting, and diarrhea within 30 hours of a meal(25). Laboratory analyses ruled out food-borne infection and it was noted that people who had not drunk the water were not ill. The water supply for the restaurant was a 100 foot deep well in limestone. Bacteriological records showed it to have been contaminated with coliform organisms (>16/100 ml) several times in the past six months. Five gallons of water was collected from the well several weeks after the incident and divided into two samples of 2 1/2 gallons each. A 50 ml sample from each was analyzed; no coliform organisms were isolated. The two samples were then concentrated by centrifugation; one sample was treated with a polyethylene flocculant. Both of the concentrated samples were positive for *E. coli*; poliovirus was recovered from the flocculated sample. No salmonella or shigella organisms were isolated. Chlorination was started and the sampling procedure was repeated; no coliforms or viruses were recovered after chlorination. This outbreak emphasizes the importance of chlorination of all water supplies as a safeguard against waterborne illness, particularly when a well has a past history of intermittent contamination. It should also be noted

that coliforms were found in a supposedly coliform-free (usual techniques detect 1 or more coliforms per 100 ml)sample of water only after concentration procedures.

The Riverside, California, salmonella outbreak (2,3,4,5)in 1965 was the largest. There were an estimated 16,000 cases based on a sample survey. At least 70 were hospitalized and 3 deaths occurred. This is a ground water supply that was not chlorinated and starting chlorination stopped the outbreak. Just why the outbreak occurred when it did is not known. The water supply was clearly incriminated but the exact source of contamination could not be determined. Of interest is the fact that before the outbreak no coliforms were detected during the routine surveillance of the water system. During the investigaton, *S. typhimurium* was isolated from the water. A surprising result of the quantitative analysis of a composite water sample from all parts of the city was that salmonellae were estimated to be ten times as numerous as *E. coli*.

Summary

Waterborne outbreaks occur because of inadequacies in water systems and deficiencies in their operation. Unless needed improvements (26,27,28) are made in both public and private water systems, it is expected that a residual number of outbreaks will continue to occur in this country. The disinfection of ground water systems would be a relatively easy and simple means to reduce waterborne disease.

Acknowledgements:

This type of review would be impossible if it were not for the activities of the Epidemiology Branch, National Center for Disease Control, in Atlanta, Georgia. The cooperation of state sanitary engineers and epidemiologists with NCDC is necessary to first report the occurrence of outbreaks and conduct investigation as to cause.

References

1. Listing of 128 Waterborne Disease Outbreaks Known to Have Occurred in the U. S., 1961-1970. Environmental Protection Agency, Cincinnati, Ohio (available on request).

2. "A Waterborne Epidemic of Salmonellosis in Riverside, California, 1965, Epidemiologic Aspects." Amer. Jour. of Epidemiology, 93(1):33-48 (1971).

3. Boring III, J.R., et al., "Isolation of *Salmonella typhi-murium* from Municipal Water, Riverside, California, 1965." Amer. Jour. of Epidemiology, 93(1):49-54 (1971).

4. Ross, E.C., et al., "*Salmonella typhi-murium* Contamination of Riverside, California, Water Supply." JAWWA, 58(2):165-174 (1966).

5. Greenberg, A.E., Ongerth, H.J., "Salmonellosis in Riverside, California." JAWWA, 58(9):1145-1150 (1966).

6. Weibel, S.R., et al., "Waterborne Disease Outbreaks,1946-60." JAWWA, 56(8):947-958 (1964).

7. Eliassen, R., Cummings, R.H., "Analysis of Waterborne Outbreaks, 1938-45." JAWWA, 40(5):509-528 (1948).

8. Gorman, A.E., Wolman, A., "Waterborne Outbreaks in the United States and Their Significance." JAWWA, 31(2):225-275 (1939).

9. Reddick, A.R., Aycock, K.E., "Water - A Vehicle of Disease Dissemination." Jour. S. Carolina Med. Assn. 67:56-60 (1971).

10. Schroeder, S.A., et al., "A Waterborne Outbreak of Gastro-enteritis in Adults Associated with *Escherichia coli*." Lancet, 6(7545):737-740 (1968).

11. National Communicable Disease Center, Foodborne Outbreaks Status Report for 1967, 38 pp. (1968).

12. Vigil, J. et al., "Nitrates in Municipal Water Supply Cause Methemoglobinemia in Infant." Public Health Reports, 80(12):1119-21 (1965).

13. Miller, L.W., "Methemoglobinemia Associated with Well Water." JAMA, 216(10):1642-3 (1971).

14. Carlson, D.J., Shapiro, F.L., "Methemoglobinemia from Well Water Nitrates: A Complication of Home Dialysis." Annals of Internal Medicine, 73(5):757-759 (1970).

15. Public Health Service Drinking Water Standards - 1962. USPHS Pub. No. 956, U.S.Govt. Printing Office, Washington,D.C. 61 pp. (1969).

16. Roueche, B., "Three Sick Babies." The New Yorker (Oct 5,1968).

17. Herman, L.G., et al., "Detection and Control of Hospital Sources of Flavobacteria." Jour. Amer. Hosp. Assn. 39:72-76 (1965).

18. Glass, A.C., Jenkins, K.H. Statistical Summary of Municipal Water Facilities in the United States January 1, 1958. USPHS Pub. No. 1039, U.S.Govt. Printing Office, Washington,D.C. 54 pp. (1963).

19. Statistical Summary of Municipal Water Facilities in the United States January 1, 1963. USPHS Pub. No. 1039, U.S.Govt. Printing Office, Washington, D.C. 66 pp. (1965).

20. Private Communication- Nevada Division of Health (June 1967, December 1970).

21. "Selenium Poisons Indians." Science News Letter, 81:254 (April 21, 1962).

22. Morse, L.J., et al., "The Holy Cross College Football Team
*23. Hepatitis Outbreak." JAMA, 219(6):706-8 (1972).

24. "Plumbers Must Chlorinate Home Piping." American City, 86(3):38 (1971).

25. Mack, W.N., et al., "Isolation of Poliomyelitis Virus from a Contaminated Well." HSMHA Health Reports (In Press).

26. McCabe, L.J., et al., "Survey of Community Water Supply Systems." JAWWA, 62(11):670-87 (1970).

27. Craun, G.F., Jennelle, E.M., "Field Survey of Rural Public Water Systems." Presented at Winter Meeting of Amer. Soc. of Agricultural Engineers, Chicago, Illinois (Dec.7-10,1971).

28. Whitsell, W.J., Hutchinson, G.D., "The Forgotten Water Consumer." Presented at Winter Meeting of Amer. Soc. of Agricultural Engineers, Chicago, Illinois (Dec.7-10,1971).

*23. Taylor, Floyd B. "The Holy Cross Episode". Jour. AWWA, 64(4):230-232 (1972).